# THE PARALLELIZATION OF HELMHOLTZ EQUATION RELATED TO BREAST CANCER GROWTH

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To my beloved parents, siblings and friends.

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## ABSTRACT

Detecting breast cancer at an early stage will decrease the mortality rate and improve the cancer treatment successfully. This research focuses on the parallelization of the mathematical modeling on breast cancer growth using one and two dimensional Helmholtz equations. Finite difference method (FDM) is chosen to discretize the Helmholtz equation in order to generate a large sparse grid solution. Some numerical iterative methods are used to simulate the grid solution. The numerical methods under consideration are alternating group explicit (AGE), Red Black Gauss Seidel (RBGS), Gauss Seidel (GS) and Jacobi (JB) method. The alternative numerical method can be detected and quantified by comparing and analyzing the numerical methods under consideration in the aspect of run time, number of iterations, maximum error, root mean square error and computational complexity. Domain decomposition technique of the parallel AGE, RBGS and JB can be applied to decompose the full domain solution into subdomains. The message passing among the neighbourhood of subdomain can be done efficiently using MATLAB Distributed Computing Software. This technique is a straight forward implementation on a distributed parallel computer system (DPCS) because of the non-overlapping subdomain feature. The computer system architecture of DPCS is a single instruction multiple data stream (SIMD) and well suited to support the high computational complexity of a large sparse matrix. The development of DPCS is based on the Linux platform with eight processors of Intel® Core™ Duo Processor architecture and MATLAB Distributed Computing Software version R2011a. The visualization of one and two dimensional of breast cancer growth are captured using Comsol Multiphysic version 4.3a. The parallel performance evaluations of parallel AGE, RBGS and JB are measured in terms of run time, speedup, efficiency, effectiveness and temporal performance. As a conclusion, the parallel algorithm of AGE is superior than RBGS, GS and JB for solving one and two dimensional Helmholtz equations for breast cancer growth early detection.

## ABSTRAK

Pengesanan kanser payudara pada peringkat awal akan mengurangkan kadar kematian dan meningkatkan rawatan kanser dengan jayanya. Kajian ini memberi tumpuan kepada penyelarian model matematik ke atas pertumbuhan kanser payudara menggunakan persamaan Helmholtz berdimensi satu dan dua. Kaedah beza terhingga (FDM) dipilih untuk mendiskrit persamaan Helmholtz dengan menjana penyelesaian grid jarang yang besar. Beberapa kaedah lelaran berangka digunakan untuk mensimulasikan penyelesaian grid. Kaedah berangka yang dipertimbangkan adalah kaedah kumpulan selang-seli tak tersirat (AGE), kaedah Gauss Seidel Merah Hitam (RBGS), kaedah Gauss Seidel (GS) dan kaedah Jacobi (JB). Kaedah alternatif berangka dapat dikesan dan diukur dengan membanding dan menganalisis kaedah berangka yang dipertimbangkan dalam aspek masa, bilangan lelaran, ralat maksimum, ralat punca min kuasa dua dan kerumitan pengiraan. Teknik penguraian domain AGE, RBGS dan JB digunakan untuk mengurai penyelesaian domain penuh ke dalam beberapa subdomain. Mesej yang dihantar melalui subdomain berdekatan boleh dilakukan dengan cekap menggunakan Perisian Pengkomputeran Teragih MATLAB. Teknik ini adalah pelaksanaan terus di dalam sistem komputer teragih selari (DPCS) kerana ciri subdomain yang tidak bertindih. Senibina sistem komputer DPCS merupakan arahan tunggal pelbagai aliran data (SIMD) dan didapati sesuai untuk menyokong pengiraan matriks jarang yang besar lagi rumit. Pembangunan DPCS adalah berdasarkan pada platform Linux dengan lapan pemproses senibina Intel ® Core ™ Duo dan Perisian Pengkomputeran Teragih versi R2011a MATLAB. Gambaran satu dan dua dimensi pertumbuhan kanser payudara dirakam dengan menggunakan *Comsol Multiphysic* versi 4.3a. Penilaian prestasi selari AGE, RBGS dan JB diukur dari segi masa, kecepatan, kecekapan, keberkesanan dan prestasi sementara. Kesimpulannya, algoritma selari AGE adalah lebih baik daripada kaedah RBGS, GS dan JB untuk menyelesaikan persamaan Helmholtz berdimensi satu dan dua bagi pengesanan awal pertumbuhan kanser payudara.